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A COMPARATIVE VERIFICATION STUDY OF MOS AND NGM-PERFECT PROG (PP) FOR SOUTHERN NEW ENGLAND

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INTRODUCTION

During the spring of 1987, the National Weather Service instituted a new system of numerical guidance based on output from the Nested Grid Model (National Weather Service, 1987). These objective forecasts are produced by statistical equations which were derived using a modification of the perfect prog technique (Klein and Lewis, 1970). This paper presents the results of a study comparing the NGM perfect prog (PP) forecasts and the LFM based Model Output Statistics (MOS) forecasts for probability of precipitation (PoP) and maximum/minimum temperature during the 1987 warm season. Three stations in southern New England were used in the study - Boston Ma (BOS), Providence RI (PVD) and Hartford Ct (BDL). The verification began on May 22 for BOS and PVD and on June 17 for BDL, which were the days PP forecasts first became available to the field. In addition, both sets of equations were examined in an attempt to help explain why certain tendencies and characteristics were observed. The cold season equations were also examined in an attempt to forsee if these tendencies would continue and/or if others might appear.

DIFFERENCES BETWEEN PERFECT PROG (PP) AND MOS

The primary difference between MOS and true PP is the relationship between the predictand and the predictors. For MOS equations, an observed predictand is related to model forecast predictors. Therefore, a data sample of model forecasts is used to derive the equations (Glahn and Lowry, 1972). In PP equations, an observed predictand is related to other weather variables which are observed at the same time or prior to the valid time of that predictand (Klein and Lewis, 1970). For more information on the development of statistical guidance, consult Carter, 1987.

In developing the NGM-PP equations, the Techniques Development Lab (TDL) used a modified PP approach. Instead of using a sample of observed upper air data, parameters were interpolated from a data sample of initial LFM fields. LFM, rather than NGM, initial fields were used because insufficient NGM fields were available to provide an adequate sample (National Weather Service, 1987). Other operationally significant deviations from strict PP, relating specifically to either the PoP or Max/Min temperature equations, are discussed below. For a more detailed explanation of the NGM-PP development, consult NWS Technical Procedures Bulletin #369.

WARM SEASON VERIFICATION

1. PROBABILITY OF PRECIPITATION

As Table 1 indicates, the most significant tendency of the warm season PoPs was that PP was consistently wetter than MOS. While MOS was better than PP overall, based upon Brier score comparisons, Table 1 also shows that PP did tend to do better at projections where precipitation events were more frequent. This was also due primarily to PP's consistantly higher PoPs.

There are three main reasons for PP's higher PoPs. The most prominent cause is the NGM's moist bias, which is primarily a result of the model's cold bias (Carter, 1987 and Phillips, 1987). These biases also tend to increase at longer projections, which was also evident in PP. Table 1 shows how PP's mean PoP steadily increased with increasing projection while MOS's mean PoP actually showed a slight decrease with time.

Secondly, PP (unlike MOS) does not tend to follow normal climatic conditions. PP PoP's will often deviate too much from the climatic mean frequency of precipitation events, especially at longer projections (NWS, 1987). This results in PP having higher PoP's, especially when the PoP is over 50%. This factor is especially important during the warm season, when the frequency of precipitation events is not as great as it is during the cool season.

The third reason PP displayed consistently higher PoP's than MOS has to do with the thresholds used for certain binary predictors. A binary predictor is one where its value can be set to 0 or 1 depending on whether a certain threshold is exceeded. Binary predictors are very prevalent in many MOS and PP equations especially PoP, and are used quite often with predictors like snow cover. Predictors such as mean relative humidity (RH) and quantitative precipitation (QPF) are often used as both binary and continuous (using the actual value of the predictor) variables within the same equation. It is important to remember that equations with binary predictors can have large changes in their predictands with very small changes in a predictor value (Maglaras and Carter, 1986 and Maglaras, 1987).

PP uses a binary threshold for surface-490mb mean RH of 70%. Values of 30%, 50%, 70%, and 90% were used as possible thresholds in development (NWS, 1987), but only 70% was selected for this group of equations. MOS uses thresholds ranging from 60% to 90%, with the large majority being 75%, 80%, and 85%. This means that if both equations were applied to the same model which has a mean RH in the 70%-85% range, this factor would greatly contribute to PP having a higher PoP than MOS. This is especially significant because the coefficients of these PP binary terms are very high, ranging between .135 and .165. This translates to a 13.5%-16.5% difference in the PP PoP if these terms are "turned on". Similar coefficients are used for binary QPF terms in PP with a threshold value of 0.10 inches.

This makes PP very sensitive to tight gradients in the NGM. For example, if an NGM run with a mean RH of 69% and a QPF of .09 inches generates a PP PoP of 30%, an otherwise identical run with a mean RH of 71% and a QPF of .11 inches would produce a PP PoP of roughly 55%-65% (depending on the specific equation being used). While MOS is also sensitive to tight model gradients (Maglaras, 1987), its differences are not as extreme as PP because the coefficients of MOS's binary terms are smaller. Additionally, a typical MOS equation has more terms than PP (MOS has about 10 to 12 terms while PP has about 5 to 7 terms) which can help to smooth out the large differences caused by tight gradients. PP's low threshold value of 70% (relative to MOS), however, brings these important binary mean RH terms into play more often than MOS, with the large coefficients often resulting in significant differences between PP and MOS. The combination of this factor and the climatological aspects discussed earlier can often explain differences between the two products when no strong synoptic scale differences can be found between the LFM and the NGM.

It is important to note that these PP PoP equations (as well as MOS PoPs) are regionalized, so the same equations are used for all stations within a specified region. The warm season PP PoP equations discussed above are used for the region stretching from Maine south through Philadelphia PA, and west from the east coast through the Great Lakes states.

2. MAXIMUM/MINIMUM TEMPERATURES

As Table 2 indicates, MOS easily beat PP for all projections except the 4th period of both cycles. PP's 4th period success is primarily due to the fact that climatology is not as important in PP, especially at longer range projections, as it is in MOS (NWS, 1987). This is especially significant because the warm season in southern New England was cooler than normal. This temperature anomaly explains why the overall mean algebraic error for PP did not seem to reflect the NGM's cold bias, while MOS seemed to show a slight warm bias. Notice, however, that PP averaged over 1 degree colder per forecast than MOS for the 0000 GMT cycle, and over 1.5 degrees per forecast colder for the 1200 GMT cycle.

There are two principle reasons for PP's cold bias relative to MOS. The most important, of course, is the the NGM's cold bias (Phillips, 1987 and Carter, 1987). Despite the fact that all of the usual low level thermal predictors like 1000mb temperature and 1000-850mb thickness were eliminated from PP (NWS, 1987), the 1000-500mb thickness field (which was forced into all of the equations) has a large enough cold bias to result in a PP cold bias.

The second reason has to do with the use of the U component of the 1000mb geostrophic wind (Ug) as a predictor. This predictor appears in all of the equations and has very high positive coefficients. This results in forecast temperatures being lowered significantly with an easterly Ug (i.e. sea-breezes or back-door cold fronts), which is a negative value. For example, if an NGM run with a 14 knot west (270) 1000mb Ug produces a PP max temperature forecast of 85 degrees, then an otherwise identical NGM run with a 10 knot east (090) 1000mb Ug could produce a max temperature forecast ranging from 80 to as cool as 70 degrees.

While this cooling factor is very useful in forecasting temperatures at coastal stations such as BOS and PVD where sea-breezes are common and have a major effect on warm season temperature forecasts, it can create problems at inland stations like BDL where an easterly wind does not have as great a cooling effect. PP does recognize this, with the Ug coefficients for BOS being much higher than for BDL, but the cooling was still overforecast at all locations. Table 3 shows how PP was much better at BOS than at PVD and BDL, which was primarily due to this factor.

Note that both PP and MOS temperature equations are site-specific (i.e. a separate set of equations is used for each station as opposed to the regionalized equations used for PoP's). The problem with Ug discussed above, however, has been observed at other stations, especially within the Eastern Region.

An important fact to remember when using PP is that all of the predictors used in the temperature equations are valid 12 hours before the valid time of the forecast temperature (i.e. for a 36 hour max temperature forecast which is valid at 0000 GMT, all of the predictors used are valid at 24 hours or 1200 GMT (NWS, 1987). As a result, a significant intra-period change might not be picked up by the PP temperatures, while MOS, which uses predictors at the beginning, middle and end of a period, is more likely to recognize the change. For example, a PP max temperature forecast is less likely than MOS to account for a stong cold front forecast to pass through at 1500 GMT. This also makes PP a little more sensitive to model mis-timing than MOS.

Finally, PP does not have a consistancy check to ensure that a max temperature forecast is not lower than an adjacent min temperature forecast (or vice-versa). This occurred for three consecutive runs at BOS during September. MOS does have such a check. TDL is aware of this problem, and recommends adjusting the inconsistent forecast to the previous period's forecast.

OUTLOOK FOR THE COOL SEASON

On October 21, NMC implemented a change to the NGM which will reduce the model's over-estimation of radiational cooling (consult Phillips, 1987 for more details). This should significantly reduce the model's cold bias, although just how much is not exactly known at present. Also unknown is how this change will impact the model's moisture fields. Regardless, this change will have a definite impact on PP. The following discussions refer to the equational problems discussed above as they relate to the cold season.

1. COOL SEASON POP'S

The high coefficients used in PP's binary mean RH terms increase slightly in the cool season equations. In addition, the QPF binary predictor's coefficient for 0.10" doubles, while an additional binary predictor for QPF of 0.01" is added to all of the equations. Table 4 shows how potential PP PoP's will change with only slight differences in certain parameters. Based on this, we can expect to continue to see higher PoP's from PP compared to MOS. How the forthcoming changes to the NGM will affect PP's PoP's is unknown at this time.

Note that the regions used for the cool season PP PoP's are different from the warm season equations. The cool season PP equations analyzed above are used for all stations east of the ed above are used for all stations east of the Appalachians from Portland Me south through Georgia. Consult NWS, 1987 for complete PP PoP regions and Maglaras, 1987 for complete MOS PoP regions.

2. COOL SEASON TEMPERATURES

The 1000mb Ug will continue to be very important during the cool season. Some very cold forecast temperatures can be expected from PP during cold air damming episodes. TDL has run a number of past cold air damming cases and found that PP "clobbered" MOS. A concern, however, is that this factor might produce a reverse bias. First, a strong west wind behind a cold front might produce temperatures that are too warm, despite the cold advection. This was true for the first cold episode in the northeast during the first week of October. PP's temperature forecasts were several degrees warmer than MOS, which was itself several degrees warmer than what was observed. Both models had roughly the same 1000-500mb thicknesses through the period. Second, an east wind during the cool season often has a warming, rather than a cooling effect, especially if the wind is due east or southeast. How the changes in the NGM will affect PP's temperature forecasts is unknown at this time.

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Attachments (Tables 1 through 4)

CYCLE	PROJECTION	% PP IMPROVEMENT OVER MOS	MEAN MOS PoP	MEAN PP PoP	# OF PCPN EVENTS
	24 HR	-4.7 %	22.3	24.1	62
	36 HR	+0.9 %	25.4	25.7	78
00Z	48 HR	-15.6 %	23.9	26.9	63
	60 HR	-3.5 %	22.8	26.8	78
	OVERALL	-5.4 %	23.6	25.8	281
	24 HR	-0.3 %	22.2	24.7	76
	36 HR	-4.1 %	23.4	24.2	63
12Z	48 HR	+3.2 %	22.2	25.8	74
	60 HR	-2.3 %	21.6	26.4	60
	OVERALL	-0.6 %	22.3	25.3	273

TABLE 1. Verification statistics for Warm Season PoPs. A negative PP improvement over MOS means that MOS was better than PP. There were 350 forecasts per period for the 00Z cycle and 348 per period for 12Z.

CYCLE	PROJECTION	MEAN ABS ERROR		MEAN ALG ERROR		% IMPROV OVER MOS
		MOS	PP	MOS	PP	
	24 HR MAX	3.39	3.90	+1.39	+0.55	-15.0 %
	36 HR MIN	2.84	3.29	+1.39	+0.62	-15.8 %
00Z	48 HR MAX	4.12	4.75	+1.71	-0.29	-15.3 %
	60 HR MIN	3.32	3.22	+0.99	+0.16	+3.0 %
	OVERALL	3.42	3.75	+1.37	+0.26	-9.6 %
	24 HR MIN	2.45	2.61	+0.69	+0.09	-6.5 %
	36 HR MAX	4.15	4.67	+0.90	-0.55	-12.5 %
12Z	48 HR MIN	3.00	3.14	+1.22	-0.05	-4.7 %
	60 HR MAX	4.98	4.93	+1.33	-1.66	+1.0 %
	OVERALL	3.65	3.84	+1.03	-0.54	-5.2 %

TABLE 2. Same as TABLE 1 but for warm season temperatures.

CYCLE	STATION	MEAN ABS ERROR MOS	MEAN ABS ERROR PP	MEAN ALG ERROR MOS	MEAN ALG ERROR PP	% IMPROV OVER MOS
	BOS	3.89	4.03	+1.94	+1.00	-3.6 %
00Z	PVD	3.22	3.68	+0.94	-0.13	-14.3 %
	BDL	3.08	3.49	+1.21	-0.18	-13.3 %
	BOS	4.16	4.08	+1.66	+0.02	+1.9 %
12Z	PVD	3.52	3.66	+0.35	-0.73	-4.0 %
	BDL	3.17	3.76	+1.09	-1.01	-18.6 %

TABLE 3. Same as TABLE 2 but for all projections at each station.

MEAN SFC-490MB RH	QPF	PP FORECAST POP
69 %	NONE	20%
71 %	NONE	35% - 40%
71 %	.02"-.10"	50% - 55%
71 %	.11"	80% - 85%

TABLE 4. PP PoP's for a given model run with only the differences shown above.